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National Hydrology Research Institute
Institut national de recherche en hydrologie

Environment CANADA Environnement
2056174K VOL 88 ISS 38 880500
EXC # 001
GB 707 N42
NHRI CONTRIBUTION

OOFF

Inland Waters and Lands Directorate
Saskatoon Saskatchewan Canada

Direction generale des eaux interieures et les terres
Saskatoon Saskatchewan Canada

Canada

ISSN 0838-1992

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SCIENTIFIC RESEARCH PROGRAMME

NATIONAL HYDROLOGY RESEARCH INSTITUTE

NHRI Contribution No. 88038

May 1988

MANAGEMENT PERSPECTIVE

The national programme plan for research sets broad priorities for research direction while maintaining sufficient scope to respond to emerging priorities and individual initiative.

It permits choices for funding between competing research proposals which are otherwise indistinguishable from the point-of-view of scientific interest.

This plan outlines a hierarchy of programmes, projects and studies which are addressed by individual annual action plans. Such a structure provides great flexibility at the study level as the research leads to new discoveries and understanding. The less easily changed programme and project levels are designed to address research priorities relevant to the broad range of issues with which the Department is concerned.

The programme set was organized and prepared after extensive discussions with scientists and managers in the National Hydrology Research Institute.

PERSPECTIVE DE GESTION

Le plan du programme national de recherche établi de vastes objectifs prioritaires à l'égard de l'orientation que doivent prendre les travaux de recherche, tout en leur laissant suffisamment de latitude pour satisfaire aux nouvelles priorités et aux initiatives individuelles.

En matière de financement, le plan permet de choisir parmi des propositions de recherche concurrentes qui, autrement, seraient impossible à différencier du point de vue de l'intérêt scientifique qu'elles présentent.

Le plan décrit, par ordre d'importance, divers programmes, projets et études faisant l'objet de plans d'action annuels et individuels. Une telle structure assure une grande souplesse au niveau de l'étude, ce qui est particulièrement utile, compte tenu des nouvelles découvertes et des connaissances acquises grâce à la recherche. L'établissement de niveaux plus rigides pour certains programmes a pour but d'assurer qu'on accorde la priorité aux travaux de recherche sur la vaste gamme de questions auxquelles s'intéresse le Ministère.

Le programme a été structuré après de nombreux entretiens avec les scientifiques et les gestionnaires de l'Institut national de recherche en hydrologie.

T. Milne Dick
Director/Directeur
May/mai 1988

ABSTRACT

This report organizes hydrological, chemical and biological scientific research activities at the National Hydrology Research Institute into three programmes.

The first addresses the need to determine historical variations in the Canadian climate and assess the potential influence of future climate change on some of the most sensitive and important elements of the water regime and the environment.

The second deals with the impact of man's activities on the hydrological and biological cycle. All water supplies and associated biota are affected by land and energy use to a greater or lesser degree. This programme is designed to understand and document key hydrological processes and develop methods to predict the impact of physical and chemical changes on surface and ground water, on sediment, and on aquatic fauna.

A third programme looks at the hydrological and biological systems in our northern environment. The particular sensitivity of the North requires that it be regarded as a special case. The programme will develop the fundamental knowledge base required to determine the factors that control water availability in the North, assess the effects of major energy and other economic developments on the northern hydrological system and assess the ecological impact of pollutants introduced by airborne transport or by local development.

Lastly, the basic plan for communicating research and advice to various target audiences is outlined.

RÉSUMÉ

Le présent rapport classe dans trois programmes différents les activités de recherche scientifique dans les domaines de l'hydrologie, de la chimie et de la biologie qui sont entrprises à l'Institut national de recherche en hydrologie.

Le premier programme a pour objet de déterminer les variations climatiques qui se sont produites antérieurement au Canada et d'évaluer la mesure dans laquelle elles peuvent influer sur les futurs changements climatiques de certains des éléments les plus délicats et importants des bassins hydrologiques et de l'environnement.

Le deuxième programme porte sur les répercussions qu'ont les activités de l'homme sur les cycles hydrologique et biologique. Toutes les sources d'alimentation en eau et les biotopes connexes subissent plus ou moins les répercussions de l'utilisation des terres et de l'énergie. Ce programme est conçu de façon à nous faire comprendre et connaître les principaux processus hydrologiques et à élaborer des méthodes qui permettent de prévoir les effets qu'auront les changements physiques et chimiques sur les eaux de surface, les eaux souterraines, les sédiments et la faune aquatique.

Le troisième programme a pour but d'étudier les divers systèmes hydrologiques et biologiques du Nord. La nature particulièrement délicate des questions touchant le Nord exige qu'on leur porte une attention toute spéciale. Ce programme permettra d'élaborer la base de connaissances élémentaires, base qui est essentielle à la détermination des facteurs contrôlant la quantité d'eau disponible dans le Nord, d'évaluer l'incidence des grands projets de développement énergétique de économique sur les bassins hydrologiques du Nord et de déterminer les répercussions des polluants résultant du transport aérien ou du développement local sur l'écologie.

Enfin, le rapport précise le plan fondamental qui a été étali à l'égard de la communication des résultats de recherche et des avis aux divers public cibles.

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OVERALL PROGRAMME PLAN

A review of emerging environmental issues has identified three research programmes within which NHRI will work.

Projects and studies which develop a broad interdisciplinary, with multidisciplinary, approach to environmental issues will be encouraged within this programme set. When funding permits, collaborators, visiting scientists and graduate students will be used to extend the scientific manpower resources of NHRI.

The three science research programmes are:

1. Hydrological Processes and Climatic Change;

2. Man's Interaction with the Hydrological Cycle:
   Impacts on Surface Water, Ground Water and Aquatic Ecology; and

3. Northern Water Systems.

In addition to these, there is a fourth programme on Scientific Communications. This will follow traditional and new methods of transferring technology and information. Advice and review services fall within this programme.

As well as the scientific research programmes, the Institute will apply its expertise to specific client-identified problems either on an *ad hoc* basis or by incorporating them within individual scientific projects.

If feasible, the Institute will enter into collaborative agreements on work sharing for client-identified projects. When work by NHRI benefits only the NHRI client and not the public at large, costs will be recoverable.

Programme and project definition is a dynamic process. As ideas and concepts develop, projects will be reviewed and updated. Annual work plans will usually relate to studies and projects. However, when a work plan is not entirely in accord with this scientific plan it will be in accord with the general mandate of C&P and DOE.

PROGRAMME 1. HYDROLOGICAL PROCESSES AND CLIMATE CHANGE

OBJECTIVE:

To determine historical variations in the Canadian climate and to assess the potential influence of future climate change on some of the most sensitive and important elements of the water regime and of the environment.

SCIENTIFIC BACKGROUND AND PROGRAMME RATIONALE:

Increased levels of CO_2 and other radiatively-active gases in the atmosphere are expected to lead to significant climate change in the next few decades. From the Canadian point-of-view, one of the most important of the predicted changes is an increase of the annual mean temperature by 3° to 5° Celsius at mid- and northern latitudes. Temperature increases of this magnitude will likely be accompanied by significant changes in the major components of the hydrological cycle, i.e. in precipitation, evapotranspiration and run-off. The exact nature of these changes is still speculative, but preliminary studies suggest that changes in the water regime may be amplified compared to those in the temperature regime.

Since most aspects of the Canadian economy and environment are extremely dependent upon the temperature and water regimes, it is of paramount importance that Canada develop an understanding of possible climate changes and potential impacts on the hydrological cycle.

The climate programme is subdivided into projects which address the key scientific issues of climate change in Canada. Each project is the focal point for a number of individual scientific studies with specific objectives designed to meet the programme goals.

PROJECT: 1.1. Natural Hydrological Cycle

OBJECTIVE:

To be able to describe the transport and exchanges of water between the atmosphere, surface storage and subsurface waters in order to contribute to sound and reliable decisions on water policies.

RATIONALE:

A dominant characteristic of the hydrological cycle is its variability. Extreme events such as floods and droughts occur infrequently in time and in space but with devastating intensity and results. In order to determine if the climate is changing, as well as to assess the impact of any change on the water regime, it is necessary to understand various facets of the natural hydrological cycle, its variability and its interactions with climate. Shifts from classical basin-scale hydrology to nation-wide or global hydrology also require the development of new methods and techniques that spatially integrate important hydrological variables and are accurate over large areas.

OUTLINE:

Basic studies related to the hydrological cycle will proceed in collaboration with other researchers in Canada and elsewhere. The emphasis will be on the moisture and vapour fluxes in and immediately above the ground. There may be a requirement to consider world-wide progress on this important subject which is being addressed by the Global Energy and Water Experiment (GEWEX).

Work on the project is divided into a series of studies.

STUDY: 1.1.1. Areal Evaporation and Transpiration

OBJECTIVE:

To find an accurate and reliable method for determining evaporation and transpiration over large areas.

SCIENTIFIC RATIONALE:

Current methods for estimating average evaporation, evapotranspiration or transpiration over large areas are very inaccurate. As evaporation is a major component of the global water cycle, it is necessary to be able to compute its influence and effect accurately.

New ideas and methods made possible by computer technology may provide better theories or models.

RELATION TO DOE PRIORITIES:

Conservation and management of water, especially in semiarid regions, is very inefficient without reliable measurements of evaporation which often exceeds the rainfall supply.

The implications of climate change cannot be evaluated without reliable evaporation estimates.

STUDY OUTLINE:

In cooperation with the Water Resources Branch (IWD), the Hydrometeorological Research Division (AES), the Saskatchewan and Alberta Research Councils, the Prairie Farm Rehabilitation Administration (PFRA), and Provincial Ministries of Environment:

- compare existing evaporation/evapotranspiration models;
- improve measurements and estimates of evaporation from snow;
- improve areal measurements and estimates of evaporation and evapotranspiration.

NATIONAL PROGRAMME:

1.5 - Water Management Research

STUDY: 1.1.2. Areal Snow and Soil Moisture

OBJECTIVE:

To develop a reliable method of measuring soil moisture, snow depth and water equivalent over large areas using available remote-sensing data.

SCIENTIFIC RATIONALE:

The water balance, droughts and the reduction of floods depend on reliable measurements of snow and soil moisture over large areas. Interpretation of remotely-sensed data to obtain useful hydrological information is quite inexact. Better knowledge of the characteristics of electromagnetic signals which identify soil moisture, snow depth and snow water equivalent, is necessary.

RELATION TO DOE PRIORITIES:

Mitigation of floods and droughts is essential for water conservation and sustained use. Proper interpretation of snow data will be extremely important for managing large international basins, such as the Great Lakes and addressing soil moisture concerns in the agricultural areas of the country.

STUDY OUTLINE:

In cooperation with the Canada Centre for Remote Sensing, the Alberta and Manitoba Remote Sensing centres, the Caltech Centre for Remote Sensing, the Inland Waters Directorate and Water Resources Branch, the Saskatchewan Research Council, the Hydrometeorological Research Division (AES), the Canadian Parks Service, the universities of Saskatchewan and Calgary and the Rocky Mountain Forest and Range Experiment Station of the U.S. Forest Service, improve the application of remote-sensing techniques to the study of regional hydrological problems by investigating the dielectrical properties of snow, ice, soil, water and other terrain elements, their reflectance and spectral characteristics and the changes induced in them by the three phases of water.

NATIONAL PROGRAMME:

1.5 - Water Management Research

STUDY: 1.1.3. Interaction of Surface and Ground Water

OBJECTIVE:

To understand the interaction of ground water and surface water in order to resolve scientific questions associated with transfer of water, toxic-chemical migration, acid precipitation, water supply and ground-water protection.

SCIENTIFIC RATIONALE:

The significance of surface-water/ground-water interactions for water balances, toxic-chemical migration, acid-rain impacts, water supply via artificial recharge and the development of ground-water protection guidelines are important but in many cases are poorly quantified.

RELATION TO DOE PRIORITIES:

Fundamental research on ground-water/surface-water interactions are a prerequisite for the development of a rational water management policy and the economic development of Canadian water resources.

STUDY OUTLINE:

Pathways and factors affecting pathways will be investigated in selected Canadian hydrological environments.

NATIONAL PROGRAMME:

1.5 - Water Management Research
4.1 - Toxic Chemicals
4.2 - LRTAP

PROJECT: 1.2. Historical Climate and Hydrology

OBJECTIVE:

To obtain reliable time-series data on hydrological and meteorological variables in order to develop reliable physically-based models of the impacts of climate change on water systems.

RATIONALE:

Knowledge of trends in climatic conditions in Canada over the past few decades are important in determining if our climate is changing, how fast it is changing and whether it is warming or cooling. Understanding the magnitude and effects of climatic changes in ancient times is necessary for assessing the potential impacts of future changes. Moreover, the validation of any models of climate change requires data against which the models can be tested.

OUTLINE:

Historic meteorological data and past hydrological events will be evaluated and correlated to provide consistent data sets for verification of theories or models. Such data collection should include information acquired and published elsewhere.

Work will proceed with separate studies.

STUDY: 1.2.1. Past Floods and Water Levels

OBJECTIVE:

To determine the effects of past climate change on the water levels of lakes, rivers and coastal wetlands.

SCIENTIFIC RATIONALE:

Climate change is believed to have a significant effect on the water levels of Canadian rivers, lakes and coastal wetlands as a result of changes in precipitation, evaporation, snow melt run-off and sea level. Many of the processes controlling water levels are poorly understood and, as a result, our predictive abilities are inadequate. These problems may be partially overcome by analysing past water-level records in relation to climatic variability.

RELATION TO DOE PRIORITIES:

Improved understanding of the effect of climate change on water levels is essential for the proper management of Canadian water resources. For example, changes in river and lake levels can have important consequences for the development of hydro-electric projects and for flood and drought forecasting. In addition, rising sea level is likely to result in the flooding of coastal wetlands.

STUDY OUTLINE:

In cooperation with the Freshwater Institute (DFO), the Inuvik Scientific Resource Centre (DIAND) and the Polar Continental Shelf Project (EMR).

- analyse storm surges in the Beaufort Sea and the resulting changes in water level in the Mackenzie Delta as a "field" experiment to determine the effect of rising sea level on the hydrological regime of the Mackenzie Delta.

- study the historical record of high-stage events in the Mackenzie River system to determine the chronology of sediment stratigraphy in backwater sediment trap locations.

NATIONAL PROGRAMME:

1.5 - Water Management Research

STUDY: 1.2.2. Palaeoclimate from Ice Cores

OBJECTIVE:

To use the atmospheric record trapped in ice cores to extend the global record on climate and anthropogenic degradation of the atmosphere.

SCIENTIFIC RATIONALE:

Dry snow zones, at high altitudes or high latitudes, preserve an annual record of temperature, precipitation, atmospheric gases, radioactive constituents and aerosols. Through ice-core analysis, their history and trends can be determined. Correlation with similar records from other areas permits the establishment of teleconnections and the possibility of assessing global trends and feedback mechanisms. These are required for developing realistic global climate models that can be used to predict likely climate and water supply scenarios for Canada.

RELATION TO DOE PRIORITIES:

Any change in the Canadian climate will impact every sector of the economy. DOE has identified this as a major priority. The precipitation record in the ice cores provides a vital time series in the context of past water supply and likely future trends - an issue addressed by the new Federal Water Policy. Ice cores also trap atmospheric pollutants. The record can therefore be used to establish a time series for LRTAP. Most of the best high-altitude and high-latitude core sites lie in the north. Thus, this one project addresses four of DOE's priority areas.

STUDY OUTLINE:

In cooperation with the Canadian Climate Centre, the Arctic Institute of North America, the universities of Calgary, Grenoble, Alaska, Chicago, New Hampshire, and the US National Science Foundation.

- link the areal mean long-term temperature and precipitation series to semi-permanent or preferred planetary wave structures in the middle troposphere.
- cross-correlate the areal mean temperature and precipitation time series with each other and with the net mass balance time series from Mount Logan.
- establish spatial correlation patterns to indicate regions having a similar climatic history to that of Mount Logan.
- investigate and explain the apparent discontinuity in the isotopic record below the troposphere.
- document evidence of the Chernobyl signal as a LRTAP indicator.
- develop and refine ice-flow models for analysis of the stratigraphic record.
- analyse volcanic and other acid signals.
- study the CO_2 variation with altitude to augment its interpretation in the Mount Logan core.

NATIONAL PROGRAMME:

1.5 - Water Management Research

4.2 - LRTAP

PROJECT: 1.3. Impact of Climate Change on Water Supply

OBJECTIVE:

To develop theories and models which are directed to the supply of water and its variability.

RATIONALE:

Assuming that climatic change will produce a warming trend, it is necessary to assess potential impacts on various aspects of the hydrological cycle. Climatic warming may alter traditional atmospheric circulation patterns and affect precipitation over large parts of Canada. Research is required on the variables affecting current water supplies and problems and possible solutions to reduced supplies.

OUTLINE:

Work will focus on aspects of water supply or specific problems significant to the West. Water supplies from glaciers and the limitations on water resources imposed by droughts require assessment. Remedial measures for conservation of supplies will be considered.

STUDY: 1.3.1. Mountain and Glacier Hydrology

OBJECTIVE:

To solve problems related to mountain and glacier hydrological systems. To interpret the growth and decline of glaciers and establish a method or model to estimate water supply from observable meteorological variables.

SCIENTIFIC RATIONALE:

Existing hydrological models do not successfully account for the annual run-off from glaciers and mountain snowpacks. Fundamental knowledge is needed on climate/glacier/run-off relationships, on liquid water storage in the mountains and its movement through different media, on the prediction of peak flows, on jøkulhlaups, and on surging glaciers. The capability to reliably model different alpine hydrological systems is still needed.

RELATION TO DOE PRIORITIES:

A better knowledge of mountain hydrology is required: (a) by hydro-electric power planners and water managers for flood forecasts and run-off, (b) for domestic, industrial and agricultural water use, and (c) to assess impacts on fisheries, mining, recreation and navigation. Almost one-third of the international boundary with the United States abuts our glacierized and mountainous regions therefore many boundary waters issues will be influenced by mountain hydrology. Glaciers straddle interprovincial boundaries, are prominent features in National Parks and cover 150,000 km^2 of the north.

STUDY OUTLINE:

Research studies will be undertaken in collaboration with university researchers both national and international. Routine data collection on mass balance will be obtained through contract with the private sector. Elements of the study are the:

- investigation and modelling of the physical processes governing the movement of water through a glacier;
- development of techniques for the surveying of englacial and subglacial water;
- development of a full understanding of the response of glaciers to meteorological variables in order to be able to simulate glacier mass balance, water production and glacier movement;
- maintenance and development of a fundamental data set of meteorological and hydrological variables;
- documentation of recent glacier variation history in the Cordillera;
- maintenance of a national information data base on snow and ice resources.

NATIONAL PROGRAMME:

1.5 - Water Management Research

STUDY: 1.3.2. Drought Frequency

OBJECTIVE:

To assess the impact of climate change on drought intensity and frequency.

SCIENTIFIC RATIONALE:

The incidence of drought is expected to increase with climate change. As a result, it becomes necessary to understand the impact of man's action, through increased demands, on water resources coupled with the impact of water droughts on streamflow, lake levels and ground water levels.

RELATION TO DOE PRIORITIES:

As identified in the Federal Water Policy, the reoccurrence of drought results in a need to encourage and promote water-demand management approaches and conservation technology in order to extend limited supplies so as to minimize the impact of a water drought.

STUDY OUTLINE:

In cooperation with the Prairie Farm Rehabilitation Administration, Inland Waters Directorate and Provincial Ministries responsible for water resources management, undertake studies to:

- determine the natural impact of past droughts on ground-water and surface-water supplies;
- determine the role of land use on the conservation of water and the impact of land management practices on water supplies.

NATIONAL PROGRAMME:

1.5 - Water Management Research

PROGRAMME 2. MAN'S INTERACTION WITH THE HYDROLOGICAL CYCLE: IMPACTS ON SURFACE WATER, GROUND WATER AND AQUATIC ECOLOGY

OBJECTIVE:

To understand and document key hydrological processes and to develop methods to predict the impact of physical and chemical changes on surface and ground water, on sediment, and on aquatic fauna.

SCIENTIFIC BACKGROUND AND PROGRAMME RATIONALE:

The long-term quality and productivity of our air, land and water resources are influenced by man's activities and the management of these resources. In keeping with Canada's commitment to preserve and manage these resources for future generations, it is necessary to understand hydrological processes and man's interaction with aquatic systems. Although a key to successful surface- and ground-water management is the prevention of pollution before it occurs, there remains the legacy of past ignorance to be cleansed or mitigated.

Managing and maintaining water quality is linked in a complex way to the health and diversity of aquatic species. Physical or chemical alterations in the aquatic environment often create adverse reactions in bacteria or plankton communities which can propagate through the entire food chain to threaten man. Knowledge of physical, chemical and biological processes that affect surface and ground-water quality is required for rational water management. For example, although the role of the natural biota in breaking down toxic compounds in aquatic systems is not yet understood, the use of microbes to restore or isolate polluted aquifers holds much promise.

The impacts programme consists of two projects, each with a spectrum of individual studies, which address the major sources of man-made environmental stress.

PROJECT: 2.1. Impacts of Land Use and Agriculture

OBJECTIVE:

To determine the relationship between the quantity and quality of surface and ground water in order to contribute to the development of rational policies and planning to sustain water resources.

RATIONALE:

Land use practices alter the rates of evaporation, transpiration, infiltration and run-off. Where water is relatively scarce, planning for land use may be usefully applied to increase water availability. Concomitant applications or release of nutrients and toxic substances may accummulate in surface and subsurface reservoirs to the detriment of water quality and to the danger of aquatic fauna.

OUTLINE:

The studies will use selected basins and areas to establish the processes and the variables controlling the partitioning of water supplies in a systematic way.

Methods or models to predict the effect of changing practices will be developed to aid planning studies.

STUDY: 2.1.1. Effects of Agrarian Land Use on Water Quality and Quantity

OBJECTIVE:

To develop theories and models to predict the impact of changes in land use on the quantity and quality of surface and subsurface water.

SCIENTIFIC RATIONALE:

Quantitative predictions of the impact of land use on the quality and quantity of surface and subsurface water are not feasible except for very limited situations.

RELATION TO DOE PRIORITIES:

Effective water resource planning depends very much on knowing how land use affects the water resource. Conservation of water may be accomplished by land manipulation.

Assessment of developments on water resources is not feasible without appropriate connections being made between land use and water resources.

STUDY OUTLINE:

This project will utilize selected areas or basins in collaboration with Agriculture Canada, the Inland Waters Directorate, Alberta Environment, the Alberta Forestry Research Branch and the University of Saskatchewan to investigate such subjects as:

- Irrigation practices,
- Tillage practices,
- Snowmelt,
- Forestry practices,
- Drainage practices,
- Surface transport of chemicals and applied nutrients.

NATIONAL PROGRAMME:

1.5 - Water Management Research

STUDY: 2.1.2. Wetlands

OBJECTIVE:

To determine the contribution of wetlands to the hydrological cycle and assess the implications of wetland drainage.

SCIENTIFIC RATIONALE:

The management of wetlands has long been a contentious issue in North America. Wetlands, covering 14 per cent of Canada's landscape, represent millions of hectares of surface water available for evaporation and precipitation. Wetlands also contribute to ground-water recharge, flood control, pollution abatement and wildlife conservation. The impacts of indiscriminant drainage of wetlands is not clearly understood. Destruction of wetlands may cause disbenefits to both landowners and society.

RELATION TO DOE PRIORITIES:

Since wetlands are an integral component of Canada's water resources, the conservation and management of wetlands is in keeping with DOE's commitment to the management and preservation of Canada's water resources and wetlands.

STUDY OUTLINE:

In cooperation with Ducks Unlimited, the Canadian Wildlife Service, Alberta Forestry, Lands and Wildlife, Manitoba Natural Resources, the Saskatchewan Department of Parks, Recreation and Culture and the Saskatchewan Research Council:

- examine the role of wetlands in the hydrological cycle.
- determine the implications of pothole and slough drainage on the quantity and quality of ground-water recharge, surface run-off and soil salinity control.
- examine the hydrological implications of integrated water management practices as a result of wetland consolidation.

NATIONAL PROGRAMME:

1.5 - Water Management Research

STUDY: 2.1.3. Prairie Lake Ecology

OBJECTIVE:

To determine source-sink relationships and the physical processes controlling biological production in Prairie lakes in order to improve existing models and develop methods to reduce eutrophication and improve water quality.

SCIENTIFIC RATIONALE:

Water is a scarce commodity on the Prairies. Interprovincial rivers provide the major water supply to some areas but eutrophic lakes and reservoirs are the only sources of water for human and agricultural needs in many areas. Long-term improvements in water quality require better understanding of the processes leading to eutrophication in order to devise cost-effective amelioration methods. In addition to deleterious effect of excess plant nutrients, herbicide and pesticide residues contribute to water quality concerns on the Prairies.

RELATION TO DOE PRIORITIES:

The quality of water in lakes and rivers is a major interest of DOE. This study is directed toward developing the scientific expertise and the knowledge required to prevent further degradation of water quality on the prairies and to develop strategies for future improvements.

STUDY OUTLINE:

Improvements in water quality can be achieved by reducing man-made nutrient (or contaminant) sources or by augmenting the natural sinks. Studies will be directed towards an assessment of the relative magnitudes of various sources and sinks and the dynamic interaction between them. Attention will be focussed on the role of sedimentation and resuspension in Prairie lakes and reservoirs. Theoretical results will be incorporated into improved models of nutrient dynamics. Field data will be used to test the accuracy of simulations and to evaluate potential amelioration methods.

NATIONAL PROGRAMME:

1.5 - Water Management Research

PROJECT: 2.2. Impacts of Industry and Urbanization

OBJECTIVE:

To describe and assess the effects of the by-products of industry and urbanization on surface-water and ground-water quality and the processes by which aquatic fauna are affected in order to contribute to development of water policies and plans.

RATIONALE:

All production and use of energy results in modifications to the natural environment and eventually to the water systems. Processes and pathways, with the subsequent decay products and transfer to aquatic fauna, are not well known. Good planning and sustained use of water resources depend on controlling and mitigating the impacts of development on its quality.

OUTLINE:

Studies will focus on subjects and substances which have potential for environmental damage or where continued deterioration would have serious impacts on the use and availability of the resource. Several studies address specific issues.

STUDY: 2.2.1. Ground-Water Contamination

OBJECTIVE:

To describe and model the interactions between ground water and the aquifer materials which control the movement of contaminants in the subsurface.

SCIENTIFIC RATIONALE:

The effect of aquifer materials on the chemistry of polluted water is not sufficiently well known to permit prediction of ground-water quality as a function of time or position.

RELATION TO DOE PRIORITIES:

The pollution of ground water by toxic substances is a very serious consequence of pesticide use, of conventional industrial waste management, and of improper waste disposal. Remedies are required.

STUDY OUTLINE:

Basic studies to understand chemical interactions in porous media flow will be undertaken in the laboratory.

Field studies and analysis will also proceed at selected sites where ground-water pollution is critical.

Comprehensive physical/chemical flow models will be developed in order to assess long-term trends and to analyse existing problems.

NATIONAL PROGRAMME:

1.5 - Water Management Research
4.1 - Toxic Chemicals

STUDY: 2.2.2. Effects of Pollutants on Aquatic Ecology

OBJECTIVE:

To develop a quantitative understanding of the impacts of pollutants (e.g. toxic substances, pesticides, heavy metals, nutrients) in aquatic ecosystems.

SCIENTIFIC RATIONALE:

The knowledge base needed to establish water-quality criteria for many pollutant substances is inadequate or non-existant. Most of the current information comes from laboratory experiments with single species of a test organism and are primarily aimed at determining lethal levels. Long-term ecosystem effects may occur at much lower concentrations. Alternatively, natural processes may ameliorate the toxic or carcinogenic effects of a substance seen in sterile culture conditions. Criteria valid for lakes may not be appropriate for rivers.

Acute and subacute effects on populations and the ecosystem's functioning will provide the information necessary for developing meaningful water quality guidelines.

RELATION TO DOE PRIORITIES:

Knowledge of toxic and nutrient impacts on the river aquatic environment are essential for equitable and fair application of water quality and hazardous substance control.

Environmental assessment of the impact of land-use developments on rivers remains very uncertain.

STUDY OUTLINE:

There are three main approaches which will be used, depending on the results obtained.

- Laboratory studies, using a unique Experimental Trough System, will assess how the microbial communities are affected by pollutants and the conditions which influence acute and chronic effects.
- Large-scale experimental basin studies may be undertaken to examine impacts of applied toxic stress.
- Sampling of specific rivers, eg. Thompson, North and South Saskatchewan, will be used to define and refine the model of pollutant impacts.

External collaborations are with WeyCan (private), the Departments of Forestry and Botany, University of British Columbia, Conservation and Protection Service personnel in the Pacific and Yukon Region, and with the National Water Research and Freshwater Institutes.

NATIONAL PROGRAMME:

1.5 - Water Management Research

4.1 - Toxics Chemicals

STUDY: 2.2.3. Microbial Ecology of Subsurface Waters

OBJECTIVE:

To develop a better understanding of the role of bacteria and microbial communities in subterranean aquatic environments on the movement and degradation of organic substances.

SCIENTIFIC RATIONALE:

Almost nothing is known about the distribution of ground-water bacteria or the major environmental factors controlling their metabolism. Recent work has shown that bacterial growth can be utilized to selectively seal aquifers and control the direction of ground-water flow. Other research indicates the potential to develop bacterial strains capable of degrading specific toxic compounds. Bacteriological methods offer the possibility of economically restoring and controlling pollutants in ground water.

RELATION TO DOE PRIORITIES:

Ground-water contamination and toxic chemicals are both major priorities for DOE. This project will be aimed at developing the scientific knowledge needed to develop technology that could potentially be used to contain the spread of contaminated ground-water and to detoxify contaminated ground-water aquifers.

STUDY OUTLINE:

The study will focus largely on laboratory developmental work which will eventually be coupled to field examination and trials. Clones of bacteria from ground-water environments will be grown in the laboratory to develop those strains most capable of producing copious amounts of extracellular polysaccharides. The conditions needed for this production will be defined. Laboratory and field tests on the effectiveness of polysaccharides in sealing fractures will be run.

Bacteria will be screened for resistance to, and effective degradation of, selected toxic substances. Gene-splicing techniques will be investigated to assess the feasibility of developing specialized bacteria. Scientists from NHRI will collaborate with researchers in the Department of Applied Microbiology and the Institute of Plant Biotechnology at the University of Saskatchewan.

NATIONAL PROGRAMME:

1.5 - Water Management Research

STUDY: 2.2.4. Paleo and Current Assessment of Environmental Quality

OBJECTIVE:

To develop a reliable method of assessing environmental quality using biological methods for both existing and past conditions in lakes.

SCIENTIFIC RATIONALE:

Chemical analysis of water or sediment is not sufficient to assess the cumulative or additive effects of sublethal concentrations of toxics and their derivatives. New methods for measuring their impact are required. Benthic organisms offer the possibility of a measure of long-term environmental impacts for both current and past conditions.

RELATION TO DOE PRIORITIES:

Assessment of past and current impacts of anthropomorphic substances in the environment is an essential prerequisite for the control and elimination of harmful substances in the water cycle.

STUDY OUTLINE:

In cooperation with the Quebec and Western and Northern Regions; Water Quality Branch; Environment Canada; the Biology Department, University of Saskatchewan; the Toxicology Research Centre, University of Saskatchewan; the Biology Department, Universit/ de Montr/al; and the Biology Department, University of Calgary. This study will:

- (a) determine baseline rates of deformation in unstressed communities, (b) explore the range of variability possible in individual morphological structures, (c) assess the range of responses in different chironomid taxa and, (d) determine the impact on members of associated benthic communities - using fauna collected from variously stressed freshwater environments;

- expose cultures of *Chironomus tentans* Fab. to known toxic compounds to: (a) validate observations made on field samples, (b) calibrate morphological responses against responses to known contaminants and (c) explore specificity of response to individual, classes and/or combinations of contaminants - under controlled experimental conditions;

- establish an archival repository to (a) provide background data for future site re-assessments and (b) provide calibration materials for other laboratories involved in morphological analysis.

NATIONAL PROGRAMME:

1.5 - Water Management Research
4.1 - Toxic Chemicals

STUDY: 2.2.5. Toxic Substances in Surface Water

OBJECTIVE:

To advance knowledge of biogeochemical processes in inland waters with particular reference to speciation, interactions with nonliving substances (clay, humic matter, etc.), partitioning, and pathways under different environmental conditions. To contribute information relevant to water planning policies.

SCIENTIFIC RATIONALE:

Interactions of chemical substances and the biota are extremely complex and poorly understood. Metal speciation, microbial transformations of toxic substances, synergistic/antagonistic effects of mixtures of toxic substances, and ecological functions of humic matter, clay, and oxides, are at the frontiers of our knowledge.

RELATION TO DOE PRIORITIES:

Toxic substances in natural environments are one of the higher-priority items.

STUDY OUTLINE:

The investigation will consist of both field studies and controlled experiments involving organisms (e.g. sedimentary microbes, algae, animals) as well as nonliving substances (e.g. clay, humic matter, sulfides), and will involve heavy metals and metalloids and possibly toxic organics as well. Research projects may deal with the following areas of study:

- Use of the electron microprobe to investigate the distribution of heavy metals among different species of microscopic organisms and different nonliving substances which may act as detoxifying agents; suitable sample materials would include plankton and sediments from polluted lakes near Flin Flon.
- Synergistic/antagonistic effects of mixtures of toxic substances (metals, xenobiotics) on organisms.
- Speciation of metals as related to bio-availability, and methods for determining biologically active (bio-available or toxic) fractions of metals in sediments and water.
- Detoxification of toxic substances.
- Effects of humic matter, clay, oxides, etc. on microbial activity and the biogeochemistry and ecological effects of toxic substances.
- Microbial transformations and biological uptake of toxic substances under different environmental conditions.
- Effects of toxic substances and other factors on microbial communities and ecosystems. These studies will involve collaboration with colleagues at the Canada Centre for Inland Waters or the University of Saskatchewan.

NATIONAL PROGRAMME:

4.1 - Toxic Chemicals

PROGRAMME 3. NORTHERN WATER SYSTEMS

OBJECTIVE:

To develop the fundamental knowledge base required to determine the factors that control water availability in the North, to assess the effects of major energy and other economic developments on the northern hydrological system and to assess the ecological impact of pollutants introduced by airborne transport or by local development.

SCIENTIFIC BACKGROUND AND PROGRAMME RATIONALE:

As over 60 per cent of the flow of Canadian rivers is carried northward, the economic potential of northern rivers is high, particularly for hydro-electric development and resource industries. Although the federal government has authority over development and management of such activities in the North, a poor understanding of hydrological processes in northern environments presently precludes an accurate assessment of the effects of development. Given the fragility and low regenerative capability of northern water ecosystems, detrimental effects from development could be wide-ranging and long-term. To permit an effective balance between environmental protection and economic development, a comprehensive knowledge of northern hydrological systems is essential.

In contrast to the large supply of water in major northern rivers, the usable water supply over large land areas is relatively scarce. Much of the ground water is permanently frozen and local surface flow is small due to low precipitation. To achieve proper management of such a limited water supply, detailed information about the entire water balance in northern permafrost basins is a prerequisite. Unfortunately, even when water is most abundant during the spring snowmelt period, floods created by ice jams create frequent yet unpredictable hazards to northern communities.

The rational management of Canada's northern water resource is further complicated by the possibility of climate change which could have profound effects on permafrost environments. Furthermore, there is a real concern that some deterioration of northern ecosystems may have already been caused by airborne pollutants transported from industrial sources around the globe.

PROJECT: 3.1. Hydrology of Permafrost Zones

OBJECTIVE:

To understand the processes of water transfers and transport in permafrost zones and the interaction with the atmosphere in order to establish theories and models necessary to analyse and assess northern developments.

RATIONALE:

The hydrological cycle is profoundly different in the North. Although timing of snowmelt and run-off play a very important role in the northern hydrological cycle, these processes cannot be predicted at the present time because knowledge of hydrological processes in the North is very limited. This project is directed towards the development of an integrated understanding of the water supply and watear balance within permafrost basins and the production of a snowmelt model for use in permafrost terrain.

OUTLINE:

Studies will proceed by establishing selected areas where the significant variables may be measured.

Models and theories will be developed which will provide the hydrological response to meteorological variables. Close collaboration with hydrometeorologists will be necessary as well as the development of a network with other researchers.

STUDY: 3.1.1. Surface and Ground Water Dynamics

OBJECTIVE:

To understand and develop information and knowledge on the water balance and water supply in permafrost basins.

SCIENTIFIC RATIONALE:

At the present time it is not possible to predict spring break-up and snowmelt run-off and, therefore, to predict the quantity and timing of streamflow events in permafrost basins because the controlling processes are poorly understood. Similarly the physical and chemical mechanisms controlling the movement of water into and through the permafrost layer and the role in the hydrological cycle of the deep ground water below the permafrost layer are not well known.

RELATION TO DOE PRIORITIES:

The research will provide the knowledge to assess the effects of and restraints on economic development in the North. An understanding of northern hydrological processes is important for flood prediction, for estimating water supply, for determining water levels in navigable waterways, and for assessing the impact of hydrological changes on biological productivity of northern deltas. Northern environments are very fragile. The consequences of disturbing the permafrost and the impacts of relatively low levels of contaminants will require innovative concepts to overcome constraints imposed on economic development.

STUDY OUTLINE:

Research basins will be established in a variety of northern environments. Snow/soil interactions (soil infiltration, soil heat flux) will be studied jointly with McMaster University. Snowmelt models for predicting run-off will be developed with potential collaboration from the Hydrological Sciences Branch, National Aeronautics and Space Administration. Physical and biological processes operating in permafrost deltas will be linked through joint studies with Fisheries and Oceans and the Freshwater Institute. Physical and chemical parameters in the active layer, the permafrost and the subpermafrost regimes will be measured to develop an understanding of the processes controlling heat and ground-water movement in permafrost terrains.

NATIONAL PROGRAMME:

1.5 - Water Management Research

STUDY: 3.1.2. Response of Permafrost to Climate

OBJECTIVE:

To develop theories and models showing the response of permafrost and its soil and vegetative cover to changes in climate.

RATIONALE:

Specific attention to the thermodynamic reactions of the permafrost ice mass to climatic variables is required because of the possible impacts of climate change. If melting were to occur, the subsequent release of water could have global impacts on sea levels and also radically alter northern topography.

STUDY OUTLINE:

At selected basins, selected physical variables will be measured in the atmosphere, in the ice cover and in the permanently-frozen ground. The transfer and movement of water and water vapour will be measured and theories and models developed.

NATIONAL PROGRAMME:

1.5 - Water Management Research

PROJECT: 3.2. Northern Rivers and Lakes

OBJECTIVE:

To obtain comprehensive information on the effects of economic developments in the North and elsewhere on the physical and environmental quality of northern rivers and lakes.

RATIONALE:

Northern transportation uses frozen rivers and lakes in winter as natural highways for surface transport. Energy and resource developments may alter ice regimes in a way that may be detrimental to normal communication and transport.

The fallout of toxic substances (toxic rain) may affect the quality of the environment which is very sensitive to imposed change.

OUTLINE:

Studies will focus on physical processes relating to the formation and break-up of ice and the impact of changing natural flows. Selected areas will be selected for study and used to develop models of ice cover thickness and strength.

Water and sediment samples, as well as synoptic air samples, will be used to assess the frequency and severity of toxic pollutants.

STUDY: 3.2.1. Dynamics of River Ice Break-Up

OBJECTIVE:

To develop a comprehensive model for predicting the timing, rate, severity and effects of river ice break-up under a variety of climatic, hydrological and geomorphological conditions.

SCIENTIFIC RATIONALE:

Although break-up controls the hydrological regime of most Canadian rivers for lengthy periods each year, the entire process, from first ice deterioration to final ice clearance, is poorly understood. Because break-up progression is often characterized by a surge-stall behaviour, the resultant transient flow conditions have proven difficult to measure or predict, and form a major deficiency in annual streamflow records. This is particularly important where peak flow occurs during the snowmelt-break-up period. The maximum annual stage and greatest likelihood of flooding on many rivers occurs during break-up and thus the traditional methods of flood frequency analysis are of limited value.

RELATION TO DOE PRIORITIES:

Increased knowledge of the dynamics of river ice break-up is a fundamental prerequisite for the proper management of northern water resources, a priority issue identified by DOE and the Federal Water Policy. Specifically, it will provide DOE with the knowledge base to anticipate and evaluate the effects of water development options, such as hydro-electric projects and flow diversions, for which great potential has been identified on many of the large northern rivers. It will also lead to improved measurement and forecasting of spring discharge and maximum stage, thereby allowing the DOE issues of water supply/management and ice jam flooding to be better addressed.

STUDY OUTLINE:

- Field studies will document break-up progression and the resulting changes in river stage. (Collaboration with Trent University; future site selection with Water Resources Division, DIANA and Western and Northern Region, WRB).
- Investigate the ablation and thermal decay processes which lead to the overall decrease in ice strength and resistance. (Potential collaboration with NRCC, Hydraulics Laboratory).
- Develop quantitative theoretical models of break-up progression. (Future collaboration with U.S. Army CRREL).
- Determine the regional climatic conditions which determine the timing and severity of break-up. (Potential collaboration with AES at NHRC).
- Link appropriate run-off (snowmelt) models to break-up progression models. (Collaboration with NHRC project dealing with permafrost run-off models).
- Investigate the processes of scour and sediment transport during break-up. (Future collaboration with Sediment Survey Section, WRB).

NATIONAL PROGRAMME:

1.5 - Water Management Research

STUDY: 3.2.2. Hydrology of Northern Deltas

OBJECTIVE:

To provide an understanding of the hydrological regime of northern deltas and to develop a model to predict water levels in the lakes and wetlands of these deltas.

SCIENTIFIC RATIONALE:

Since deltas occur at the interface between two very different hydrological systems, river basins and lakes or oceans, the water-level regime of deltas is complex. For example, water levels in the lakes and wetlands within deltas are controlled by discharge in the delta distributary channels, run-off from the delta land surface, and the water level of the receiving lake or ocean. In northern deltas, the system is further complicated by river ice break-up and the existence of permafrost. Many of the problems associated with northern hydrology, for example snowmelt run-off from permafrost basins, river ice break-up, evaporation, and lack of sufficient data, also limit our ability to predict water levels within northern deltas.

RELATION TO DOE PRIORITIES:

Increased understanding of the hydrology of northern deltas will enhance our ability to provide scientific advice on environmental problems related to northern development, and allow for proper management of northern water resources. This is important for the Mackenzie Delta, the largest in Canada, since it is prone to environmental problems caused by hydro-electric development in the Mackenzie Basin, contamination from hydrocarbon production, and rising sea level due to climate change. A basic understanding of the hydrological processes controlling water levels is needed to mitigate the environmental effects of these anthropogenic influences.

STUDY OUTLINE:

- Analyze the existing water level data in the Mackenzie Delta to determine the timing, frequency, and duration of lake flooding and determine the relative importance of water balance components controlling lake levels.
- Develop model to predict lake levels in the Mackenzie Delta and their spatial and temporal variations.
- Measure sediment balance of delta lakes and the relationship to the hydrological regime (NOGAP Project).
- Determine the chemical and nutrient balance of delta lakes (Collaboration with Freshwater Institute, Winnipeg).
- Determine the effect of rising sea level on Mackenzie Delta water levels by using Beaufort Sea storm surges as a physical analogue.
- Use lake sediment core data to provide proxy data on long-term lake level fluctuations.

NATIONAL PROGRAMME:

1.5 - Water Management Research

STUDY: 3.2.3. Northern Water Quality

OBJECTIVE:

To develop an understanding of the natural and anthropogenic changes occurring in the water quality of northern rivers and lakes.

SCIENTIFIC RATIONALE:

Water quality data for northern rivers and lakes are relatively sparse. Long-term information for northern basins with respect to physical and chemical characteristics of water, nutrient variability, metals, trace elements, and toxic substances are lacking. An understanding of the relationship between northern hydrological processes and the chemical composition of northern waters is necessary if natural and anthropogenic changes are to be successfully assessed.

RELATION TO DOE PRIORITIES:

The North may experience extensive natural resource development in the future. Better knowledge of, and more data on, the various components influencing the chemical composition of northern river and lake waters will be required to adequately assess potential environmental impacts of mining, oil, gas and hydroelectric development. It is also a prerequisite for determining biological impacts and ultimately the range of environmental impacts on the whole northern ecosystem.

STUDY OUTLINE:

A number of research basins will be established to represent a variety of northern environments. The relative contribution of the snowpack, snowmelt run-off, ice cover, ground water and rainfall to the water quality characteristics of rivers and lakes will be investigated. This research may be linked through joint studies to Fisheries and Oceans, the Freshwater Institute, the Water Quality and Sediment Survey Branches (IWD), and NHRI's Ground Water Division.

NATIONAL PROGRAMME:

1.5 - Water Management Research

PROGRAMME 4. SCIENTIFIC COMMUNICATIONS

OBJECTIVE:

To effectively communicate the results of research programmes to scientific colleagues, to officials, and to the public.

RATIONALE:

Research work is not completed until the results and new knowledge are transferred to potential users.

Effective communication enhances the reputation and credibility of Departmental scientists and officials. Efficient information exchange with other national and international scientists leads to equal and reciprocal treatment.

OUTLINE:

The communications programme has six main components which are described below.

1. PUBLICATIONS:

1.1. **Scientific Papers**; Target: Scientists both national and international.

Publication of research papers in journals efficiently and effectively communicates with researchers in the same discipline. Papers are offered to journals of good reputation with effective review and editing. Publication in journals by staff enhances the reputation of the Department, the Institute, and the scientist.

1.2. **Science Reports**; Target: Senior management and technical staff of C&P and DOE, external technical staff and planners at the national level.

Science Reports will address current issues and be interdisciplinary when possible. They might be an analysis of a problem, a report of an investigation, a monologue or a literature review. Science Reports will be IWD publications and thus be published in both official languages. They will be written both by Institute scientists and by outside contract writers. The subject matter of these reports may not just reflect the current work of NHRI as they will deal with contemporary issues and problems confronting the Department. Credible Science Reports provide a direct means of enhancing the reputation and visibility of the Institute not only within DOE but also with professional environmental planners, engineers, managers, and the informed public.

1.3. **Newsletter**; Target: Management and professionals in DOE and external scientists and researchers.

A newsletter can inform a large number of clients or potential clients of the work and products of the Institute. It is essential to keep placing the products of the Institute before clients to improve the frequency of their use. The message may have to be repeated. A newsletter provides a cheap and effective means of doing this.

The newsletter will promote the programmes, expertise and products of NHRI and increase its visibility and reputation. It will be concise, attractive, bilingual, and frequent enough to maintain continuity.

1.4. **Unpublished Reports**; Target: Variable but national.

Unpublished reports contain analysis and data or are the text of papers submitted for publication but judged of sufficient importance for immediate but limited release.

Print runs are limited. They will contain an abstract in both official languages. When appropriate, and additional summary in the form of a "management perspective" may be included.

Unpublished reports provide an essential means of archiving research output and enable large data reports, too voluminous for journal publication, to be referenced in other papers and reports. All unpublished reports will have distinctive NHRI covers. They will be maintained in perpetuity in an open file in the NHRI library.

1.5. **Technical Note**; Target: Client

Technical notes are prepared as reports, but are essentially long letters intended for the use of a single client.

The client will be identified in the rationale for the report. Such reports will be archived and provided with distinctive covers to promote Institute visibility and image.

2. CONFERENCES:

Target: National/International Scientists/Engineers.

The Institute, either alone or in collaboration with associations or universities, will organize international and national conferences, symposia and workshops. These activities improve the visibility and recognition of NHRI as a centre of expertise. Editing and publication of proceedings in the NHRI Symposium Series provides an additional benefit to the organizing scientists and the Institute.

3. MEDIA EXPOSURE:

Target: General Public, National.

Opportunities for non-paid publicity of the right kind will be identified and exploited if possible. Press releases will be prepared to cover events at NHRI, interesting results from new reports, and other matters of general public interest.

4. T.V. TAPES:

Target: Public and Scientific Sector

Video tapes outlining the overall scientific programme of NHRI and details on individual projects will be prepared. These will then be used to provide a comprehensive and standardized explanation of the work of the institute to the general public and visiting scientists. In this way it may be possible to provide a much better overview of the field work component of the research programme. The time frame will be several years due to the difficulty of obtaining footage from the more remote sites.

The tapes will also travel with scientists to conferences and symposia to further advertise the work of the Institute and the Department.

5. FACT SHEETS:

Target: Public Sector

Condensed information on specific scientific activities or issues will be prepared in pamphlet form to explain matters to the general public. Fact sheets concentrate on one subject and are useful for responding to specific questions by the public or media.

6. LIAISON:

Target: Management within DOE, other national and international institutes and scientists, federal and provincial agencies, ENGOs, universities, consultants and the general public.

Links will be developed with a variety of scientific and non-scientific groups involved in hydrological and related work. Information exchanges will be established.

The Communications Programme will serve as a clearinghouse for the Institute and provide DOE management and external users with rapid access to NHRI's broad hydrological knowledge base.

7. MISCELLANEOUS:

Target: Professional Groups, General Public at Local Level

When others request NHRI participation in their media promotions, e.g. radio or television interviews, staff will be encouraged to participate. A promotional film on the reserach park at Innovation Place, released for television, included an interview of the Director and such activities will be contiued.

Staff will be encouraged to speak to Service Clubs, schools, universities and at meetings in NHRC or elsewhere.